Engineers and Architects Association
OF SOUTHERN CALIFORNIA

HISTORICAL SKETCH OF THE ASSOCIATION
By A. B. BENTON

Read at Twentieth Anniversary Celebration
September 12, 1914

SUBWAYS AND TRAFFIC CONGESTION IN LOS ANGELES
Lessons from the Boston and New York Subways
By SAMUEL STORROW

Illustrated Lecture Before the Association
April 15, 1914

REVISED ROSTER OF MEMBERS

ORGANIZED SEPTEMBER 11, 1894
Los Angeles, California

Association's Officers and Directors Since Organization.

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H. Hawgood .... President
J. N. Preston .... Vice-President
F. W. Wood .... Second Vice-President
Frank Van Vleck .... Secretary-Treasurer

1896

Octavius Morgan .... President
E. L. Swaine .... Vice-President
Fred Eaton .... Second Vice-President
F. H. Olmsted .... Secretary-Treasurer
Directors—A. B. Benton, S. P. Hunt, H. Hawgood, C. S. Compton.

1897-1898

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Fred Eaton .... Vice-President
A. B. Benton .... Second Vice-President
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Directors—S. P. Hunt, H. Hawgood, J. A. Walls, J. W. Warren.

1899

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1900

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1904

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1913

Arthur B. Benton .... President
Samuel Storrow .... Vice-President
Arthur S. Bent .... Second Vice-President
H. Z. Osborne, Jr. .... Secretary-Treasurer
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1914

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Directors—A. H. Koebig, G. P. Robinson, J. J. Backus, Albert C. Martin.

Historical Sketch of the Association's Early Days

READ AT TWENTIETH ANNIVERSARY CELEBRATION, SEPTEMBER 12, 1914, AT THE COUNTRY HOME OF OCTAVIUS MORGAN

By A. B. BENTON, Past President

The birthplaces and childhood of men who have achieved large success in life are ever popular subjects for picture makers and writers. Even in this unsentimental age "Little Journeys" to the cradles of famous individuals appear in print with a frequency indicative of a ready sale for such literature. As our association has attained both length of years and the fame that always comes to any society of scientific men or artists which succeeds in keeping well alive for a term of years, and drawing to its membership a body of men active in professions intimately concerned with the progress of civilization, it cannot but be interesting on this twentieth anniversary of its founding to recall its beginnings and the men who founded it and who sustained it in the days of its infancy and untried youth.

I have taken it upon me to write this historical sketch because I delight to recall both the men and the history of this society. Of its founders but one, Fred Wood, has died; eleven, Brett, Benton Eaton, Hawgood, Morgan, Preston, Swaine, Van Vleck, Wackerbarth and Wright, are still members, and two, Aiken and Warren, resigned in removal from the city.

Our first secretaries were active engineers whose field embraced all of the Southwest, including Mexico, and the records of the early days are fragmentary to a degree. I find my own transcriptions as succeeding secretary not nearly as complete as our present secretary rightly considers necessary; so that I have had to recover from memory, from conference with charter members and from newspaper clippings considerable data set forth in this paper. It was with us as with most pioneers, we failed to realize how difficult we were making the labors of future historians by our laxity in bookmaking. If I as a pioneer had known, I would be called on to write our history in so distant a future, I am certain the records would have been much fuller and richer in story than I find them today.

The Engineers and Architects' Association of Southern California had its inception at a banquet of the Architects Association (now the Southern California Chapter, A. I. A.) held at Jerry Illich's Cafe on North Main street, in the summer of 1894. Engineer Fred W. Wood, who by nomination of Octavius Morgan had been elected an honorary member of the association, was at the banquet, and in a dinner speech proposed an organization which should include both engineers and architects.

My recollection of this occasion of twenty years ago is very vivid. As secretary of the architects it was my particular duty to remember all important happenings at our meetings, and Mr. Wood's speech especially impressed itself on my memory, because of its unusual character.

The banquet itself was much more elaborate than was customary with us; there was wine a plenty, the attendance was large, and the behavior of some of our members became more hilarious than dignified; so much so that Mr. Morgan, who presided, had to rebuke in a kindly way several of the more irrepressible. It was the first time Mr. Wood had met with us, and not having been informed of the simple customs prevailing at our feasts, he was the only one present who was in evening dress. This distinction evidently gave the headwaiter an exalted opinion of Mr. Wood's rank among us, for after having formally presented several courses to the master of the feast, who sat at the far end of the room from the service entrance, he shortened his circuit and honored our guests by making further presentations to him. Mr. Wood graciously acknowledged these until speechmaking having begun early, a vast turkey, beautifully browned, was brought for his inspection and thrust on his attention while he was on his feet and as he was getting well into his address; whereupon he unceremoniously approved the offering as "D—n fine; take it away and cut it up!" And the waiter thereafter dispensed with that formality. Mr. Wood was a brilliant speaker and his address at this dinner, I consider the most fitting for such an occasion that I have heard in the twenty years of this association. In it he suggested the organization of a society in which architects and engineers might be intimately associated to their great mutual benefit and profit, in that their professions were so akin and yet so different. He deprecated the tendency of engineers to forego the pleasure of social life, and was sure such a society would furnish both educational and social privileges hard to supply in another way. He spoke of the importance of professional men getting together to develop that "Esprit de Corps" without which it was impossible to attain the highest individual success, or to gain for our work the right appreciation of the public. He referred to the prevalence of bad design and poor construction in architectural and engineering works in the West, and plead for higher ideals, quoting Longfellow's stanza:

"In the elder days of art,
Builders wrought with greatest care
Each minute and unseen part,
For the Gods see everywhere."

He congratulated the architects on their having organized and demonstrated the possibility of maintaining successfully in Southern California an association such as was there met, and bespoke their co-operation with the engineers in a joint society.

A review of the history of the Engineers and Architects' Association since its inception on that evening twenty years ago will

show how well Mr. Wood estimated the possibilities of such a society, as well as the need then existing for its promotion. Its inauguration at a banquet was most fitting, as from its beginning until this present moment it has found its most congenial atmosphere about the dining table, and to a man its members can speak best when best fed.

The first meeting looking to the organization of the association was held at Mr. Wood's office on Temple street, not long after the banquet at which he suggested its formation. Those present were Fred W. Wood, Octavius Morgan, F. Van Vleck, E. T. Wright, J. A. Walls, H. Hawgood, J. N. Preston and one other, and they decided to call a meeting to organize. It was held at the same place, and appointed H. Hawgood, J. H. Preston and A. B. Benton a committee on constitution and by-laws. This committee met at Mr. Benton's office at 144 North Spring street, and formulated a report following closely the constitution of the American Society of Civil Engineers. The committee reported to a meeting held in Mr. Wood's office, September 11th, 1894, of which Mr. H. Hawgood was chairman and Mr. Frank Van Vleck secretary. There were present H. Hawgood, F. W. Wood, J. N. Preston, A. Wackerbarth, W. C. Aiken, A. B. Benton, Octavius Morgan, Fred Eaton, Jas. Warren, E. T. Wright, E. L. Swaine, H. E. Brett and F. Van Vleck. At this meeting the constitution and by-laws reported by the committee were adopted and the association was permanently organized, Mr. Hawgood being elected president and Mr. Van Vleck secretary.

The first paper was read by Architect J. N. Preston at a meeting held December 19th, 1894, his subject being "The Study and Practice of Architecture." There were twenty members present. It was decided that the charter list of membership be held open until July 1st, 1895. By January 1st there were twenty-seven members, and by July 1st, forty-one.

In 1896 the association, with the Southern California Chapter of the American Institute of Architects, rented and furnished a room in the Wilcox building at Second and Spring street. Previous to this meetings had been held in private offices, City Engineer Compton's office and at the Chamber of Commerce. This venture proved disastrous financially, the association and the Chapter getting deeply in debt by the purchase of furnishings and the rental of the room, and that too with no particular benefit as members seldom came to the place or consulted the books and pamphlets which had been accumulated by the association, although the secretary or his clerk were in attendance during all business hours. After an occupancy of but a few months it became evident that the Los Angeles engineers and architects allowed themselves scant leisure during the daylight hours at least, and the "headquarters" was abandoned and the furniture finally sold to apply on indebtedness. This experience was disappointing, but is a common one in our western cities where there is so great stress of business as to prevent professional men from taking time for that study and social converse that would undoubtedly be greatly to their advantage, even in a business way if they could avail themselves of them.

In 1896 Architect Norman St. Clair won a prize offered for the best design for an association seal.

The association from the first made much of its social meetings. It was, in fact, compelled to do so; as a meeting without "refreshments was never as well attended as when "dinner" was announced and finally the example of the Chapter of Architects was followed, and in 1904 all regular meetings were ordered to convene around the table. Since this recognition of a well-known scientific principle, viz., that power must be supplied, usually by the consumption of fuel, to make the wheels revolve satisfactorily, the growth of the society has been most gratifying. At one notable dinner at Redlands, in December, 1898, Engineer Joseph Jacobs perpetrated a joke on Mr. James D. Schuyler which aptly illustrated the vital connection sometimes existing between professional efficiency and avoirdupois. Engineers and architects had gone on a pilgrimage that afternoon through miles of water tunnels at the head works of the Southern California Power Company in the Santa Ana Canon. The going was not good for heavy men, and Mr. Schuyler did not feel "fit" for the response to a toast assigned him for the dinner in the evening, so delegated Jacobs to substitute for him. The subject was the advisability in certain engineering designs of putting any excess material into the "middle third." At the end of a brilliant speech advocating this, Jacobs made the practical application by pointing to Mr. Schuyler's ample girth as a "living example which conclusively demonstrated the correctness of the theory."

In the early days before the membership was large, we were entertained at the homes of members more frequently than has been practicable in later years. Mr. Lippincott was the first to open his home to the association for a social evening. His good example was followed by Swaine, Eaton, Eisen, Schuyler, Morgan (there may have been others) and the gracious custom has recently been revived by Mr. Storrow for our present comfort and felicity.

Excursions for pleasure and education have been frequent with us from the first. We began going to the Los Angeles harbor very early in our career and have many pleasant recollections of the courtesies extended by government and construction engineers in charge of the harbor and lighthouse work. Cement plants, railway and water tunnels, gas works, planing mills, big bridges, old missions, sewage reduction works, tile works, power plants, telephone exchanges, ship yards, aqueducts, reservoirs, skyscrapers, newspaper plants, mountain railways, rolling mills, beach resorts, stone quarries, Spanish barbecues—all these and and sundry others have furnished us excuses for excursions which have been con-

ducted without a single accident in the twenty years. Of old the railways furnished free transportation. That was prior to the time when it became unethical to accept a fifty cent favor from a public utility corporation, lest integrity should wabble on its seat. It was before the "unexampled rapid development of Southern California" had made architecture and engineering generally lucrative occupations.

I had a student draftsman then, a gentle youth full of all courtesy and patience, and of a marvelous perseverence withal. To him I gave the collection of association dues and the emoluments of the office, which totaled in the year 1901 $24.17. He collected dues as the widow of the Bible did hers from the unjust judge, by his importunity. He called on members so often that he "wearied" them with his persistence and shamed them with his unfailing patience, so that in the end he got their dues, out of which ten cents came to him to invest in shoes to be worn out forthwith in continuing his rounds for another year. I am glad to record that this youth is now a very successful teacher of music, he having in some way conceived a poor opinion of the opportunities afforded by the practice of architecture and engineering for the accumulation of an annual income commensurate with the physical exertion and mental strain involved in such practice. He is certain, however, that his experience gained him a reserve store of patience practically inexhaustible, which enables him to teach piano playing with joy and lightheartedness. Our annual dues at that time were one dollar, and our delinquency generally in excess of 25 per cent. If not rich, this association was happy in that the most harmonious relations prevailed between its members. The only occasion on which debate threatened to become acrimonious was over an appointment of a nominating committee on an excursion train, instead of at a regular meeting, as by the constitution required. Ex-President Mayor Fred Eaton stated that during his term he never saw the constitution, and had appointed nominating committees at "any old place," and his motion to sustain the action of President Olmsted was approved. This debate, however, lead to a revision of the constitution in the method of nominating and voting for officers.

Papers and addresses before the association were all supplied by members for several years. The first by a non-member I find recorded was by F. H. Newell in 1899. Our first president, H. Hawgood, delivered an inaugural address in which he referred to "irrigation works as of the first importance for this section." To the importance of the collection of authoritative data on which to base investment of capital; to power production and transmission; to good roads and harbor improvement. I find among the early proceedings papers by Preston on "Ventilation and Heating;" Warren on "The Arc Lamp," and on "The Electrical Transmission of Power;" Hunt, "Mission Architecture;" Benton, "Two Sciences, One Art;" Eisen, "Steel Building Construction;" Drake, "The Fisk Range Finder;" Purcell, "The Uses of Architecture in Engineering;" Miner, "The Battle of the Yalu River, and Its Influences on Naval Construction;" Halladay, "Engineering Conditions in Guatemala and Honduras;" Hawgood, "Desert and Delta of the Colorado;" Warren, "The Interior Wiring of Buildings for Incandescent Lights;" Campbell, "Water Measurements of the Los Angeles River, 1896;" Van Vleck, "The Telephone;" Lippincott, "Forest Reservation;" Olmsted, "The Water Problem of Chicago;" Miner, "Dewey's Bombardment and Capture of Manila;" Fowler, "Bridge Evolution;" Wood, "Electrical Power Plants;" Storrow, "The Firth of Forth Bridge;" Wyman, "The Evolution of Architecture in the Twentieth Century;" Meyler, U.S.A., "The San Pedro Harbor;" Mulholland, "The Water Supply of Los Angeles;" Higgins, "Automatic Telephones;" Brown, "Oiled Roads."

By far the most important papers, however, were those of H. Hawgood and E. L. Swaine, on "Harbor for Los Angeles," read before the association March 6th, 1896. These were published and were so in demand that a second edition was shortly published, together with a paper on the same subject by Capt. J. J. Meyer, U.S.A.

Preceding the reading of papers and the debate the association inspected Santa Monica and San Pedro Harbors and became familiar with their advantages. This first volume of "Proceedings" was of great value to the United States Committee on Harbor Location and to members of the Senate and House. A second volume of "Proceedings" was compiled by the writer several years later.

In 1896 the association "resolved" in favor of the "Metric System Act Now Before Congress," and so instructed the California Congressional delegates.

Also by resolution demanded better fire protection for Southern California forests.

In 1897, J. D. Schuyler presented a resolution urging "the director of the geological survey to complete the survey in California."

In 1898 our congressmen were asked to work for the Forest Preservation Act.

In 1896 the laxity of local regulations of wiring of buildings was discussed and efforts made to have them bettered were successful.

The hydrographic work of the United States Geographic Survey was commended and its extension demanded.

The association has had fourteen presidents in twenty years: Hawgood, Morgan, Swaine, Eaton, Olmsted, Eisen, Campbell, Lippincott, Fries, Rosenheim, Mulholland, Hamlin, Benton, Storrow; and but four secretaries: Van Vleck, Olmsted, Benton and Osborne. Of these officers, but one, Mr. Campbell, has died. Of the original forty-one charter members, twenty are now members.

This is not a history, but only a historical sketch, and hardly touches the last ten years of our association ilfe. In ten years from now I hope Mr. Osborne, then as now our ideal secretary, will edit and publish a comprehensive history of this Society.

Subways and Traffic Congestion in Los Angeles

Lessons from the Boston and New York Subways

ILLUSTRATED LECTURE BEFORE THE ASSOCIATION, APRIL 15, 1914

By SAMUEL STORROW

The dangerously crowded condition of Broadway, especially between Third street and Eighth street, throughout all the daylight hours, and the crowded condition of Spring street and Main street, presents a problem which we, as engineers, ought to be able to solve.

Traffic congestion is caused by a volume of traffic in excess of the capacity of the streets, which capacity is at the same time seriously interfered with by cross-currents of traffic, and especially by the right angle turn of traffic at important intersections.

Traffic Conditions Analyzed

An analysis of the traffic conditions shows that the careful studies made of street traffic in the large eastern and European cities applies equally well here in Los Angeles, excepting only that the elements are combined in different proportions.

The problem consists of devising the details of the two cures for the difficulty. One cure is to improve the traffic regulations and so actually increase the number of vehicles and pedestrians who can be passed across and around crowded street intersections, and the other cure is to re-route some of the traffic in order that it may be kept away from crowded intersections. After making three separate studies of police control of street traffic in Boston, New York, Detroit and Chicago, and having given a good deal of thought to the carefully written accounts of how much traffic is handled in New York, Paris and Berlin, I am free to say that traffic control by the police in Los Angeles is the next to worst in the whole list. The absolute lack of control in Boston is far worse than it is here. The handling of traffic in Chicago, where the turning of corners and crossing of important intersections is much more difficult than here, is incomparably the best I have seen. It is not, however, our topic tonight to discuss police control of surface traffic, but rather the relief of traffic congestion by the second method suggested, namely, the re-routing of traffic in order to take it away from crowded streets and route it over less crowded streets, and especially through subways.

The most crowded section of the city and the most crowded hour in that section is when the women's retail stores are receiving and delivering their greatest rush of customers, which is during the late afternoon, and the traffic congestion is greatest at the corners nearest the most popular stores. So much of that traffic as consists of customers bound to and from the immediately adjoining stores must necessarily be taken care of at that point. It cannot be diverted elsewhere. But all traffic which may be described as through-traffic, all traffic which is not locally in and out of nearby shops, but is in the nature of a traffic bound homeward to distant residence sections, and all traffic which is merely passing through the congested district, can be diverted by subways or elevated structures, and in such manner can be passed more rapidly through some system of lines which are kept wholly distinct from the purely local traffic to and fro among the stores of the crowded district.

Please note the great difference between this type of traffic and ordinary railroad traffic. The merchant on our crowded streets is most anxious to see a great development of what steam railroads call "idle traffic," that is to say, of people, all of whom have a little money, wandering up and down the sidewalks and wandering in and out of the stores. It is for this traffic that he prepares his shop windows and makes great displays on his counters and in the newspapers. It is this great swarm of idle shoppers who at the same moment are the life of the stores and the cause of the traffic congestion.

Every city consists of several distinct types of business centers, as, for instance, the wholesale district, the manufacturing district, the transportation centers, and the centers of the woman's retail stores. Each of these centers of business has a slightly different hour of its heaviest congestion. In New York, where these districts are widely separated, it is very interesting to see the extremely crowded condition of the streets in the light manufacturing district during the noon hour, and the almost complete desertion of the same streets at all other hours, excepting the quick, sharp rush of the homeward-bound operatives at the closing hour. This problem is being seriously felt in New York, and a great deal has been said and written on the desirability of limiting the height, and thereby the capacity, of buildings, it beng a not uncommon condition for high office buildings and high buildings adapted to light manufacturing, that they house a population of thousands, where a few years ago they contained but a few hundred people. It is even suggested by building companies now actively at work that they propose to install horizontal cars traveling through the corridors, and to charge a transportation fee for the use of their elevators and these horizontal cars.

The Development of Subways

The use of subways for the handling of traffic of ordinary street surface cars was begun in Boston by the building of the Tremont street subway. Its development has gone on until today there is a total investment in Boston in subways, exclusive of equipment, of about thirty millions of dollars. This is for a city of 500,000 people, and a city that on account of its conditions and location is more similar to the problems in Los Angeles than any other case I know.

The problem in Boston, as also here in Los Angeles, is largely the handling of a local traffic greatly congested over a small area, and the passing through this congested area of an entirely distinct traffic originating in other nearby districts, and especially the handling of this combined traffic during the rush hours of the evening, because the outward-bound rush in the evening is at once more crowded and more impatient, and shows a far greater disregard of traffic regulations and the rights of other travelers, than the inbound rush in the morning.

In New York there are two great developments in subways. The Pennsylvania railroad has spent over one hundred millions of dollars to build a crosstown subway; built for the sole purpose of the handling of local traffic. In addition to this are the subways owned by the city, which are really merely extensions of the capacity of the surface streets, and are operated to handle both through-long-distance traffic and a shorter haul, but one which here in Los Angeles would be called long distance traffic because even the short haul on the New York subway is seldom less than several stations or 15 to 20 blocks, very few passengers making shorter trips than that. These subways owned by the city, exclusive of the Pennsylvania railroad subways, represent an investment of about $175,000,000. This is wholly exclusive of surface railroads, which must go on essentially the same irrespective of whether or not the subways are built, because when subways are built the surface railways handle the purely local traffic, which is increased rather than diminished by the ease of access from suburban districts.

The number of passengers carried by the street railways of Boston during the year ending June 30th, 1913, measured at five cents apiece, is nearly one million passengers per day, or, roughly speaking, the daily movement of the entire population of the district served. This is a volume of business naturally belonging to a properly developed transportation system here in Los Angeles. This great development of business justifies the Boston City railways in paying a rent for the use of the subways, which are owned by the city, equal to the interest on the city's investment, plus a small sinking fund to retire the cost, plus a small share of the profit in the operation, and the lease also requires that the railways maintain the subways in good working order. In New York the city subways are leased to the Interborough Rapid Transit Company, who paid a rental for the year ending June 30th, 1913, of over $8,000,000 for the use of a grand total of 371 miles of single tracks, subway and elevated.

The meaning of these figures must be borne in mind by us as we study the permissable design, and costs and methods of operation of subways. We must remember that the primary business of a subway is to tap the most congested sections of the city at the most crowded hours of the day, and to deliver this traffic into the outlying ring of residence centers without allowing this through traffic to interfere with the idle traffic in and out of the stores, and without interference with the second type of through traffic, which may be called "short-haul-through-traffic." In New York the subways handle only through traffic. One is the long-haul-through-traffic, handled by fast running express trains, and the other is the short-haul-through-traffic, handled by fast running local trains, but the passengers on these local trains travel such distances that they are classed as through traffic and not as local traffic, whatever name may be applied to them.

Engineering Problems

The engineering problems met with in the construction of subways are due to the difficulties presented by the material, and especially the water through which the subway is driven, and, second, the character of overlying material, and especially the buildings which must be supported during and after construction. In New York the material to be excavated is almost entirely rock, making a firm foundation for both the subway and the adjoining buildings, so that the work in New York is extremely expensive, and yet, relatively, very simple. In Boston the materials encountered in the subway bear a close relation to what we find here in Los Angeles, varying from quicksands through mud and loose gravel to cemented gravel, with very little rock. There is a material found in the glaciated gravels in Boston, composed of mixtures of sand and cemented gravel, which behaves evry much like the shales penetrated by our three tunnels here in Los Angeles, except that it presents the additional complication of a large amount of water. The Cambridge connection in Boston, which is more commonly known as the Beacon Hill tunnel, passes for 2500 feet through this loose and yet partially cemented gravel.

The methods of constructing a subway are two. It is either built by the cut and cover system, excavating one or more trenches in the street, building the tunnel as if it were a great flume, putting on a cover, putting back the earth fill overhead, and then relaying the pavement, or else it is built as a tunnel without disturbing the surface of the street, or the buildings under which it penetrates. If built as a tunnel it is either driven with a shield forced into the material ahead and closely followed by a concrete lining without any timber lagging whatsoever, or it is built by driving small drifts and holding up the roof with timber lagging while the tunnel is gradually enlarged to full size, and the concrete lining built in place. It was generally conceded by the engineers who discussed the matter with me that building a tunnel with a shield is far the preferable method when it can be done, because the material is not exposed to the air and is continuously supported from the moment of first attack until the tunnel is wholly completed. Building the subway in an open cut and then replacing the surface is done in about one-half of the work, and is the usual method when the subway is near the surface of the street,

and especially where a cross section of the completed subway is constantly meeting pipes, sewers, and electric conduits, which must be maintained in service at the same time that they are moved out of the way.

The walls and cover of the subways in all recent construction in the East are wholly of concrete, with such steel reinforcing only as may be necessary in each given instance. I find that eastern engineers almost universally consider brick linings antiquated, expensive, and undesirable from the point of view of strength or rapid work.

Stresses Encountered

By far the most insidious stress which subways must withstand is due to water, both as water pressure and as a solvent, and as assisting electrolysis. A number of the subways in Boston have been built for miles wholly or partially below tide level, sometimes standing in salt water, sometimes in brackish water, and sometimes in fresh water, and frequently on a foundation of piles. Subways are built under Boston Harbor and New York Harbor, where the pressure of water is heavy and uniform, and under Beacon Hill in Boston, where the overhead pressure is heavy, but varies greatly under conditions of rainfall. The effect of the water pressure on the subway is immaterial as regards direct pressure, because for other reasons the subways are built more than sufficiently strong to stand the pressure. The danger seems to be from the water percolating into and through the concrete on account of its solvent action on the lime and reinforcing, and on account of its disfiguring the interior of the subways, especially at stations.

When a subway is built below the level of the street the stresses upon the roof come principally from the direct overload of material between the roof of the subway and the surface of the ground, or from such buildings as may be overhead when the subway is not under a street, and these stresses become the more dangerous if there is much water in the ground, on account of the additional water pressure and the softening of the earth and gravel, or even the presence of quick sand, making defective foundations, or subjecting the walls to the great pressure of saturated and sliding material. The heaviest reinforcement in the new subways is used when a heavy building is on or close to one side of the subway, which, at the same time is unsupported on the opposite side, either because of excavations for cellars or on account of side hill construction. A great many cases of this sort were present in the Boston subways, because Boston is a hilly city. Relatively few were present in New York, excepting when caused by buildings. Two interesting problems in New York were the Times building and the Belmont hotel. The Times building of 23 stories was already built when the subway came along, curving underneath it; which necessitated that the overload be supported both during and after construction. The Belmont hotel of 21 stories was built over the subway at the same time that the subway was constructed and, therefore, presented a far simpler problem. The principal of construction was to arrange a wholly independent system of supporting the building and subway, so that the load of the building overhead was carried through the subway to its appropriate foundations below. In both cases this problem was simplified because the foundation was on solid rock.

The Boston Leaning Tower

In Boston one of the most difficult problems was presented by the tower of the Old South church on Boylston street. This tower has always had a distinct tip towards the street under which the subway was built. The tower weighs about 5000 tons and stands on a foundation 37 feet by 42 feet, which is a load of only three-tenths of a ton per square foot, but this foundation is in turn supported on about 225 timber piles, which thus carry a load of 22 tons each. These piles were driven an unknown distance by light hammers through what was originally a marsh, with a known depth ob about 34 feet, and to or into a sub-foundation consisting of a layer of sand overlying a layer of gravel overlying about 100 feet of soft clay. The subway passes down the street in front of this tower and on the side towards which the tower was already leaning. The floor of the subway is so far below water level that at high water the water level is nearly the roof of the subway. The subway was built by the cut and cover system and it was necessary to pump the water from the trench in which the subway was built; whereby the leaning of the tower towards the subway was very greatly increased. At the same time the public library building on the opposite side of the street showed a tendency to slide into the excavation, which had encountered the soft flowing sand below water level. The excavation was protected by rows of interlocking sheet pilling thirty-five feet long, driven in the bottom of a 10-foot trench to a total depth of 35 feet below the sidewalk. In addition to this sheet piling a line of 2-inch pipe borings, spaced 10 feet apart, was put down outside of the sheet piling, and into these pipes was pumped neat cement grout, all that they would carry up to a pressure of 90 pounds. The subway was then built, and after it had been completed careful measurements showed that the water level had been restored to its original condition and the tower had essentially regained its original position of moderate tip. I am told, however, that during certain stages of the work the leaning of the tower was so noticeable that the public sometimes thought it was actually falling. An additional complication in this case was because the corners of the tower are built of very carefully cut and squared stone, whereas the curtains of the walls are made of a loose rubble; therefore, the shrinkage of the material was uneven, and the tower has always shown marked vertical cracks near its corners.

Boston's Narrow Thoroughfares

Washington street, Boston, is a very important street, too narrow for two vehicles

between the curb and the car line. It has a very heavy traffic at almost all times, and an especially heavy foot traffic during shopping hours, and a heavy discharge of operatives onto the street at noon hours and at the closing hour in the evening. The greatest possible capacity has been given to the street by forbidding automobiles or any vehicle to stand at the sidewalk except during the actual moments of loading and unloading, and this rule is very rigidly enforced. The subway was built without stopping surface traffic. The street is lined on both sides with lightly-built retail store buildings, often of soft brick in lime mortar and on shallow rubble foundations. The side walls of the subway are built actually in contact with the foundation walls of these buildings, and in many cases the bottom of the subway has been carried well below the bottom of the foundations of the buildings, so that the buildings themselves had to be held on false work while the excavation for the subway was carried still deeper and then underpinning was built to extend the old foundations of the buildings down to foundations of the subway.

Summer street is another important shopping street of Boston, where a good deal of light manufacturing is carried on. Again there is room for only one line of vehicles between the street cars and the curbs, and here, as elsewhere, it is the custom for the congested foot traffic to overlap the sidewalks and walk in the street as frequently as on the sidewalks, and here again the subway had to be built without stopping traffic on the street. The subway occupies the entire width of street from property line to property line, which in Boston means from building line to building line, because the sidewalks in Boston belong to the city and the city owns all the cellars under the sidewalks, merely permitting the abutting property owners to use this space by a permission which is frequently rescinded. The buildings on both sides of the street were built on old-time foundations of granite blocks, the footings of which extended outward into the street at very shallow depths. It was necessary, therefore, to cut out these foundations and substitute new underpinning under the store buildings in order to obtain the full width of the street for the use of the subway. Many thousand lineal feet of this type of work were done in the Boston subway, largely by contract. In a few cases the contractor was relieved of his contract on account of the serious cracks developing in the buildings, and the work taken over and done by the subway commission.

Winter street, Boston, is a street so narrow that vehicles are allowed to pass through it only in one direction, and are frequently forbidden the use of the street altogether, when the police believe that the foot passengers have a prior right. The narrow sidewalks are utterly inadequate to handle much business, and any type of surface car would completely blockade the street. Under this street the new South Boston subway was built, without stopping the traffic. The entire tier of buildings on both sides of the street now stand on new foundations, because in every instance the old foundations encroached outside the property lines at a depth less than the depth of the subway.

In the crowded sections of Boston the procedure was to permit the contractor to appear on the ground late in the evening to begin his work, and to require that he be underground, with the surface of the street restored by timber planking, at the opening of traffic next morning. The contractor brought a big force of men, ripped up the pavement, excavated five or six feet, put up a timber support for the street cars, and a new plank surface for the roadway, and thus got his men under ground, even if in somewhat cramped quarters, before the next morning. I may say that this rule is so rigidly enforced that it is thoroughly effective, and, practically, surface traffic in Boston has not been materially disturbed, whereas in New York it was often very seriously interfered with on account of the more difficult work in rock.

Beacon Hill Tunnel

The tunnel under Beacon Hill in Boston is the nearest in all its problems to what we have before us here in Los Angeles. This tunnel passes under Beacon Hill at a maximum depth of nearly 100 feet, on top of which stand three and four story brick buildings. The Beacon Hill Tunnel is built for a double-track railway of extra large cars built especially for this traffic. The standard tunnel is 27 feet wide in the clear, and 20 feet high above the top of the rail. The cost of right-of-way was nominal, as the entire land damages, including a somewhat expensive approach at the west end, was less than $43,000.

The engineers tell me that excepting at the west end, where head room was very scanty, and at the stations under the old subway at the west end, they felt free to adopt any design they pleased and any thickness of wall they pleased, and in talking it over with the chief engineer and the chief designing engineer, they told me that they adopted the greatest thickness of wall asked for by any member of the board, and that they then put in all the reinforcing steel asked for by every member of the board. The result is that the crown of the arch of concrete is 2 feet 3 inches thick; the exterior walls are 2 feet 8 inches thick, but have safety stations cut into the walls at intervals of 15 feet, reducing the average thickness of the wall to 2 feet 3 inches.

The total length of the tunnel is 2486 feet, and it consists of a main tunnel extending from the west portal 1873 feet to the Park Street station, which has a length of 613 feet. The main body of the tunnel is 1873 lineal feet long, and its construction cost $502,302, which is at the rate of $268 per lineal foot. The overhead charges, including land damages, administration, interest, etc., raised the total cost of this section to $350 per lineal foot. These figures that I am giving you now are for the part of the tunnel

known as Section I, which is all of the tunnel excepting only the Park Street station and its tapering connection to Section I. The Park Street station is built with three wide platforms, each 350 feet long, with elaborate stairways, both stationary and movable, connecting with the old subway and the street overhead. It was built under extremely difficult conditions of tunneling under a very thin cover of earth which could not be disturbed, and one end was built under an already crowded subway carrying cars during rush hours at the rate of one every 40 seconds, which could not be interfered with, and so closely under this old subway that in some places the base of the girders under its rails comes below the low roof of the lower subway. Besides all this, there were buildings for administration, operation, ventilation and drainage, in spite of which the cost of this station was $1009 per lineal foot.

We have, therefore, the example before us of Section I of the Beacon Hill tunnel at a cost of $350 per foot, including all overhead charges, or $270 per foot, construction cost only. This tunnel, as I have said, is 27 feet wide in the clear by 20 feet high above the rail. The first or main section was built almost entirely with a shield; the Park Street station was tunneled under timber lagging. It is lined throughout with concrete without reinforcing, except at the stations, at the portals, and in one place where a heavy building rests directly on top of the crown of the arch. Westward from the portal of the tunnel the houses were cut away wherever they interfered with the right-of-way. The portal is made as a two-bore tunnel to Station 3 plus 75, where there is about 10 feet of overhead material between the top of the arch and the surface of the ground. The full section then begins and continues to the beginning of the Park Street station, that is to say, to the end of Section 1 and the beginning of Section 2. The plan shows a large number of houses between the portal of the tunnel and Section 3 plus 75, and shows that many houses remained on top of the right-of-way throughout the entire length until the subway reached Boston Common. These houses are from three to six stories high, built of brick set in lime mortar, and are very frail, flimsy structures. It was of the utmost importance that settlement should not reach through to the surface, and this result was perfectly accomplished by the use of a shield which left only one-half inch of unoccupied space after the tail of the shield was pulled out from over the new concrete, and this one-half inch space was properly taken care of by forcing grouting into the grout pipes which were spaced in a ring of grout pipes to each 30 inches of tunnel. No settlement has been found reaching to the surface anywhere throughout this section. In applying this lesson to Los Angeles, I think some of you will agree with me that if you were contractors you would undertake the work here with a shield. I know that I should if it was left to me, and yet I do not consider that the shield is essential, because I have seen much more difficult work done right there in Boston, but at somewhat higher cost, without using a shield.

The Shield in Tunnel Construction

The method of construction of Section I of the Beacon Hill Tunnel was by a shield. The details call for driving of two advance drifts, in each of which the side walls were built up to a little below the springing of the arch. On the side walls a track was laid. On these tracks is a nest or car of rollers, and on these rollers stands the arch of the shield. This shield is merely a steel support for the cutting edge and an arch to hold up the roof until the following steel forms and concrete have been put in place. The shield rests on rollers, which in turn rest on the rails on the walls of the subway already built in drifts ahead of the shield. The shield itself is forced forward by a ring of hydraulic jacks pushing against the back of the shield. These jacks have a 30-inch stroke, so that the shield is pushed step by step 30 inches at a time. The jacks are then shut up, 30 inches of concrete built close behind the shield, and the shield starts ahead again on another move of 2½ feet. In this ring of concrete just mentioned a series of cast iron push bars are built, so that the jacks do not push directly on the green concrete, but push on the push bars, which in turn extend backward into older and older concrete, so as to carry the strain back to the well-set concrete and keep it off the green concrete.

The shield has already been referred to as merely the false work of an arch. The span is 27 feet. The rise from the springing line to the crown is 14 feet. It is built in two stories, that is to say, the bracing of the shield has somewhat the effect of making it like the letter A. No material changes have been incorporated in the series of shields built for the many difficult pieces of work in Boston, excepting the cutting away of some of the partition material and the base in order to get more convenient access to the sides of the work.

Construction Methods With Shield

An examination of the shield in action shows the reason for the two-story design. The upper story, above the cross bar of the letter A, is called the upper excavation chamber. The men work by pick and shovel, and throw the material down chutes to the lower floor below, from whence it is removed by trains. The upper floor serves for bringing in the concrete. That is to say, the tunnel during construction is two stories high, with a temporary timber floor at the height of the cross bar of the shield; this upper floor is used for bringing in concrete and other material; the lower floor is used entirely for carrying out excavated material.

Behind the men excavating in the face of the shield is another crew putting up the steel I-beams and form used to support the concrete. Then comes a crew of concreters putting concrete in place over this form and packing it tight up against the tail of the shield. The work is so managed that for each 30 inches advance of the shield there is built up one 30-inch ring of form and

then a 30-inch ring of concrete, and in each ring is set a line of grouting pipes, so that when the shield is immediately pushed forward on its next step of 30 inches, the half inch space remaining over the concrete between the green concrete and the material overhead can be filled by grouting forced in under pressure of 90 pounds per inch. The usual rate of driving the tunnel was usually two steps of 30 inches per day, that is to say, five feet per day, which consequently meant that two rings of concrete were built per day, and thus the green concrete is laid daily to within 2½ feet of the rear of the shield. As you know, the secret of holding up the roof of a tunnel is to get the lining into place as quickly as possible. That point has been well demonstrated here in Los Angeles, and is the experience of every tunnel engineer, though we still occasionally find advocates of keeping the tunnel lining well behind the cutting face.

The lower floor of the shield and tunnel is entirely for excavation. Trains of cars are run in such a way that there are always cars in the face of the tunnel into which material can be shoveled, it being self-evident that the shield can go ahead no faster than the material is removed, so that the contractors see to it that there is plenty of room for the men to work, plenty of means at hand for working, and plenty of cars for getting rid of the excavated material. The lower story of the false work under the arch looks directly into the shield. The heavy I-beam frames follow close behind the shield. These are the A-shaped frames to hold the forms holding the concrete. Resting on these tunuel forms is a 2-inch planking, excepting in cases where steel sheets are used. Thus next immediately behind the shield is the false work for the concrete form of the arch. The frames are steel ribs; the under form is timber; overhead, the tail of the shield, close against the gravel roof, serves as the outer form for the concrete, and into this space the concrete is rammed from the concreting floor overhead. In the working room below the men are excavating material from the face of the shield, shoveling it into cars, and these cars are arranged to stand below the chutes which lead up to the top floor where the men are at work.

The upper story of the tunnel, that is, above the cross bar of the A-frame, is used for bringing in concrete and delivering supplies, and this top story extends back through the tunnel clear to its mouth, so that the tunnel during construction contains three tracks from the portal to the face, two tracks on the lower floor and one track on the upper floor, the lower tracks being used for excavating, and the upper single track for supplies, and especially for concrete.

Removing Material

The cars when loaded are run out of the mouth of the tunnel and up onto an elevated structure built over the street, and dumped into bins, it being a requirement of the work that the hauling away from the work shall be done at night as far as possible, in order not to interfere with traffic. These upper platforms serve for dumping the excavated material into bins, and also for storing of supplies. The cars are very simple type wooden cars, side dumping.

The carrying away of the materials from the bins was done very largely by horses, because it was found that while automobile wagons were very satisfactory for loading, they were very unsatisfactory for dumping under the conditions of Boston, where the wagons at the time of dumping frequently had to pull out onto a dump too soft to hold up automobiles.

Grouting and Leakages

Inside the tunnel after it is concreted the general design is a semi-circular arch with a span of 27 feet resting on slightly battered walls 7 feet 3 inches high, which in turn rest on a heavy inverted arch that has a drop of 4 feet 3 inches. The roof of the arch is marked by the 2½-foot steps of the shield and timber forms on its under side. In the wall are safety stations 15 feet apart and 14 to 18 inches deep, with bases at such a height as will be about 6 inches above the top of the rail after the track is laid. Before the grouting is completed the roof shows evidence of leakage, and yet, when you remember that the tunnel is under 80 feet of overhead gravel with the water level well above the top of the tunnel, you realize that the leakage is very little.

After the roof of the tunnel has been grouted it is essentially water-tight. The floor is not grouted until still later, and the joints between the sections of the floor leak quite noticeably. After the floor of the tunnel has been completely grouted this leakage disappears. As I have already mentioned, there is a very considerable pressure of water on the outside of this tunnel, as in most parts of it the water level is well above the roof of the tunnel.

The Tunnel Floor

The floor of the Beacon Hill Tunnel, and in fact the floors of all tunnels and subways which I have had a chance to examine in the East, are invariably so built as to transmit the load from the roof to the floor, distributing as uniformly as possible over the floor the same load that comes on the roof, in order that no part of the foundation of the finished structure shall carry a heavier load than is directly overhead and was there before the structure was built. This concrete floor is universal in all Eastern construction and is intended to serve the double purpose of transmitting the load from the roof to the floor and at the same time of protecting the roadway and pavement from the effects of upward seeping water. This inverted arch under the floor is so universally used, and with such perfect success, that it seems impossible to advise a subway, even in this dry country, without an inverted arch for its combination of strength and waterproofing. The tendency of the load on the roof is to force the subway downward and to induce an upward tendency in the center of the subway unless counteracted by the inverted arch, and the tendency for upward seepage is very great, with a resulting deterioration of the pavement, well known to you in the condition of the heavy pavement of the Third

Street Tunnel and in the light gravel pavement of the much more steep and naturally much better drained floor of the Broadway Tunnel.

Progress Problems

Going in from the Cambridge end of the tunnel, the right-of-way was first cleared of certain obstacles and buildings, and the tunnel then dived under the buildings. The problems included the minimum of takings for right-of-way and the supporting of flimsy brick buildings on top of the arch. In this case the problem was solved by making twin arches, in order to occupy the least thickness, and then putting reinforcing steels in the concrete. The partition wall between these two arches, which, as you know, carries one-half the load overhead, is slightly under one foot thick. When the portal was finished the effect was satisfactory, although the tunnel seems to dive right into houses in an effort to get well under ground. The tunnel is primarily a single arch, and the double tunnel here discussed is merely an entrance to get into the houses, in order to occupy the least width of right-of-way practical, and the least headroom, the roof being practically a slab, although somewhat rounded at the corners to more nearly conform to the shape of the cars which were designed for this special service.

After leaving the twin portal at the western end of the Bunker Hill Tunnel, the next station or two are under houses which might be very readily wrecked in future construction; so that future cellars or walls may be built resting on the arch of the tunnel, thereby producing eccentric loads. For that reason tie-bars have been built in the roof of the tunnel for a short distance, making its roof an arched truss. Very little reinforcement was used in the walls. I ask you to take particular note that the clear span of the double-track tunnel is 27 feet, and the arch of the tunnel is built under heavy and varying loads, with no reinforcing except a few bars at the crown of the arch, which the chief engineer told me were put in at the request of a non-engineering member of the board on the argument that they could not injure, but might help, and cost very little. After leaving these tie-bars and extending eastward towards the business center of the city, the tunnel was built without reinforcement.

The method of building the tunnel under Beacon Hill was by the use of a shield as far as the section of the tunnel was uniform. At the Park Street station the section changes by expanding to the entrance of the station, which in turn has a length of platform of 350 feet. This expanding of the tunnel and the station was driven by drifting, and then expanding the drift as the concrete was put in place.

Building Subway Under Subway

It was necessary to build the new subway under and at right angles to the old subway, which had been built with no thought of future expansion. Therefore it was a very difficult matter to cut out the old foundations, because it was obligatory on the contractor not to in any way delay traffic in the old subway, where during the crowded rush hours of the afternoon a car passes every 40 seconds. The problem was to build the new subway as close under the floor of the old as possible and not to interfere with the operation of the old subway. The span of the station is 62 feet in the clear inside of the finished section. The span is formed by two arches which come together on a row of piers in the center of the center platform. The method of construction was to run an advance drift by pick and shovel. This drift has its outer edge exactly at the edge of the right-of-way, and rests against the abutting property. When this drift has advanced about 40 feet, Phase 2 is begun, which consists of cutting out the floor of the advance drift, dropping this floor to the under side of the finished section of the concrete floor. Then comes Phase 3, which is the beginning of the concreting. The lagging that was in place in Phase 2 is moved step by step a few inches into the tunnel, leaving the wall unsupported. A thin layer of concrete is put behind this lagging, and so rests against the abutting property at the very exterior edge of the right-of-way. This thin wall of concrete thus becomes the exterior main wall of the tunnel, serving the triple purpose of a lagging to hold up the abutting property and a wall on which to build the waterproofing, and at the same time serves its full value of strength. When this concrete has hardened, Phase 4 is begun, which consists of placing the full thickness of concrete, the outer face of which is against the waterproofing built on the concrete lagging just mentioned, and the inner face is the inner face of the finished subway. During this work a second drift has been run in the crown of the arch overhead, and a third drift has been run at the foot of the center columns. The three drifts are then connected together, leaving the center core unexcavated. At the same time that the concrete footing of the outer wall is being put in place a similar footing is built for the supporting of the center piers, and, of course, a third footing is being built under the second exterior wall. False work for the arch is then put in place, resting on the center core and on the steel columns of the center footing, and thus the concrete of the overhead arch is put in place. This overhead arch is built very lcose to the excavating, usually only a few feet away.

The advance drift, called Phase I, may be described as the upper right hand corner of the completed structure. The extremely soft and loose character of the material required a fairly strong roof if the span of the roof was allowed to get more than a very few feet. That is the reason why the method of construction just described was used, namely, in order that the span of the roof should always be very small. Drainage of this drift is effective, because the breasting out and other work at lower levels provides the necessary drainage.

Phase 2 followed closely on Phase 1. It is really a breasting out of the drift in Phase 1. The advance drift of Phase 1 is overhead, with its face some 40 feet beyond the men working in the breast of Phase 2. By

this system all the drainage is concentrated in one place, namely, in the lowest tunnel, and this system is made the more effective by keeping the faces of the several drifts close together. The total amount of drainage was at times very great.

Concreting the Arches

The advancing concrete arch rests on the unexcavated core. The supports for the form are arranged to provide a line of traffic for bringing up the concrete to build this arch. The waterproofing fabric was tacked up against the under side of the lagging. This lagging was left in place, but the cross timbers were all taken out as the concrete advanced, allowing the lagging to rest directly on the concrete. To offset the tendency of the material overhead to sink when the lagging rotted, the engineers left a system of grouting pipes in the concrete and forced this grouting through these pipes under heavy pressure, so that the timbers were thoroughly saturated with rich grouting, making an additional waterproofing on the outside of the arch. As a fact, no shrinkage has ever been found extending even through the thin cover to the surface, and you can see that the total shrinkage cannot exceed two inches, even after the lagging is entirely decayed.

After the concrete of the arch had sufficiently hardened, the core of earth which had heretofore held up the arch was excavated, and the floor was then laid. In general the roof sections of concrete arching were put in with a length of about 30 to 60 inches, whereas the floor sections were put in with a length of 10 to 15 feet.

Where the tunnel expands into the Park Street station it is changed, as I have just described, from a single bore to a double bore, that is to say, from its standard width of 27 feet single-arch double-track tunnel to the station width of 62 feet, double-arch. Here, as elsewhere, grouting pipes stand thickly through the concrete arch and serve the double purpose of showing the location of serious springs of water in the overhead material and of permitting the forcing of grouting at heavy but varying pressures, not only through the whole surface of the arch, but especially into those places where leakage was found excessive. Similar grout pipes were left in the floor.

The Subway Stations

The Park Street station is a very good example of a station adapted to handling large crowds. It is built in what is now the standard form in all Eastern subways, that is to say, it is an island station. Passengers are loaded into the cars from an island platform on one side of the cars, and taken out of the cars onto the side platforms. In this instance, as is usually the case, passengers pay their fares to enter upon the center or island platform. When the train runs into the station it stops between this island and the outer platform, the outer doors are opened, passengers are discharged onto the outer platform, so that they can pass out to the street through turnstiles that prevent entrance from the street. As soon as the car is sufficiently empty, and at such hours long before it is wholly empty, the doors on the entrance or island side of the cars are thrown open and the crowds of passengers on the island platform move rapidly into the cars. So quickly is this done that one minute is considered ample time for emptying and loading during heavy rush hours. This is an extremely satisfactory arrangement, because it prevents the outgoing and incoming passengers interfering with each other. It is extremely well developed in Boston, but has not been at all developed in New York subways, and, I am told, is forbidden by law here in Los Angeles. Certainly there is no example worse than the wholly unnecessary congestive interference of passengers at the Pacific Electric station on Main Street.

The design of the Park Street station includes three platforms separated by two sunken tracks which flank each side of an island platform, access to which is only by passing through the "pay-as-you-enter" gates. The two outer platforms are the "exit platforms," from which stairways and elevators lead to the street. The track is so sunken and placed that the edges of the platforms are one inch from the door sills on the sides of the car and level with the floor of the car.

The waterproofing of the station walls is accomplished by using extra care in packing concrete, by thoroughly grouting the roof of the arch, and by covering with the canvas diaphragm. The walls to a height of eight feet are then lined on the inside with split hollow tiles arranged with the grooves vertical, to make vertical passageways for any water that gets through, and on this tiling the glazed tiles are cemented so that the effect is that the glazed tiles are furred from the concrete, leaving an inch air space to provide air circulation and drainage. The effect is a decided success, and I am told by the engineers, and have had it pointed out to me in a number of cases, that glazed tiles have been uniformly unsuccessful wherever used directly against brick or concrete surfaces. We have a very good example of this in the staining and leakage through the arch of the new Hill Street tunnel.

The glazed tile work extends from the platforms to a height of about eight feet all around the station. It is finished in two or three colors, and provided with panels for posters. Above the tiling the surface is finished in a white paint of special composition, which is replaced from time to time, and is found to have very good holding and lasting qualities, and to spread the light extremely well. Should any important leakage develop, holes are drilled and additional grouting is forced through.

The success of the waterproofing is proven by the fact that stains on the walls are very unusual, even in places where the entire tunnel, including the roof, is below water level.

Where the new subway is built under the old subway the headroom is very scanty, so that the lowest headroom on the platforms of the Park Street station is 9½ feet. The flat roof, where headroom is scanty, is built

of steel beams. Overhead is the old subway, and it was necessary to build this work without interfering with the constant traffic of cars overhead.

The Boylston Street Subway

This subway, just completed, is known as the Boylston Street subway. It passes through the residence sections of Boston for the purpose of taking traffic off of the street and allowing the long distance traffic to have the right-of-way over local traffic and not be stopped at every street corner. There is no strictly local traffic in any subway that I have studied. The whole value of subways seems to be to carry heavy traffic through a given section of the city from a congested center on one side to a distributing point on the other. The Boston electric railway system consists of suburban car lines radiating like the sticks of a fan from the out-of-town end of the subways, which concentrate to loops at the down town ends.

The residence section over the Boylston Street subway was built about 25 years ago on filled ground. The subway is in the streets or parks, and is built by "cut and cover." A number of serious problems were presented by this unstable and shifting foundation. The Hotel Somerset rests on piles which are driven through fill and quicksand and do not reach a stable base. The subway under the street in front of the hotel was built much below water level; in fact, the high water level is about the roof of the subway, and, being built by "cut and cover" methods, it was necessary to pump the water out of the trench, which induced a sliding of the hotel towards the open cut. This problem was met by the use of steel interlocking sheet piles and by lines of pipe driven at frequent intervals and grouted under heavy pressure. The tall square tower of the Old South Church, which I have already described as the leaning tower of Boston, and the heavy square tower of Trinity Church presented even more difficult problems. The Old South Church stands on piles not driven to a firm foundation, and because of the tilting and subsidence of this tower the engineers in charge of the Trinity Tower built a much heavier foundation, which stood without disturbance as the subway passed by.

The Boylston Street subway passes under a small arm of the bay called the Fenway. A coffer dam was built above and below, the pond pumped out, and the tunnel built in what is techniaclly known as "in the dry," but if you had been there and seen the pumps you would have used another expression. The material at this point was a very soft mud, and the floor of the subway was necessarily supported on piles. When the pond had been pumped and the cut started for the subway it was found that the walls of the cut had to be held apart by heavy timbering, because the material on which the structure was founded was quicksand and soft flowing clay. So great was the inflow of water, and especially the inflow of quicksand, that the lagging for this open cut was steel sheet piling, and the cut was further divided by very frequent cross walls and the excavation carried forward as a series of slices across the subway, built one after the other, so that the development of this step by step system is now known a the "slicing method." It is extremely successful where serious quicksands or much water is met with, and, as I have mentioned, in this instance the roof of the subway was several feet below normal water level.

When the excavation for the Boylston Street subway had been completed, the outer walls of the excavation were gotten into position and held up by lagging. Then the waterproofing was put on the walls and floor, either directly against the lagging or, more usually, against a thin wall of concrete, which in turn stood against the lagging. The waterproofing diaphragm is made of heavy layers of heavy cotton fabric, heavy enough to be called light canvas, all thoroughly saturated with an asphaltic composition put on hot enough to be flexible, but of such composition that it holds flexibility even at temperatures below zero.

Waterproofing of Subways

The waterproofing of the subways in Boston and New York is effected in two ways, by a dense and rich concrete grouted on the outside with pure cement, and by a watertight coating or diaphragm on or near the outside of the concrete. The amount of water leaking into the subways of New York and Boston, including the subways under the harbors, is extremely small. Even when the tunnel has been built with a shield it sometimes has been found practical to get a layer of asphaltic material on the outside of the concrete. The principal dependence for waterproofing is upon the asphaltic coating, and it was found that absolute watertightness could not be obtained by any inflexible construction, because there was always a certain shrinkage or hardening of the concrete, which developed minute cracks sure to leak under water pressure, a leakage, however, that was fully stopped by the flexibility of the asphaltic coating, and it was further found that this coating must be built with heavy cotton fabric, because all attempts with paper and burlap failed to hold their watertightness and strength, and it was also found necessary that the asphaltic diaphragm should be flexible enough to be turned back while construction work went on and then smoothed into place again, and that it should adapt itself to cutting and be flexible at all temperatures.

The greatest dependence for waterproofing is upon a preparation known as "Minwax," which is flexible at temperature around zero, and is capable of being built up by several piles laid overlapping to essentially any degree of thickness and strength, and even then is flexible enough to be folded back out of the way, and never seems to lose the ability of making a tight joint with new work. Two methods of applying this coating are in use. The first application in the subway is usually on wooden or concrete lagging of the side walls, which are first mopped with a hot asphalt coat to act as binders for the cotton fabric, which is thus put on as thick as desired, each layer being mopped very much as roofing paper is ap-

plied. You are to understand, however, that the fabric is not paper, but is a high-grade cotton cloth, about equivalent to a light canvas. The second part of the subway to be waterproofed is the roof. The waterproofing is fastened directly to the under side of the lagging, which is left in place, and, if of wood, is preserved against rapid decay by grouting pipes which pass through the concrete and through the lagging, so that after the arch is finished and the grouting pumped in the lagging is well embedded in neat cement. It is found as a fact that this method of work thoroughly fills the space between the arch and the under side of the roof of the excavation, thus insuring that the contractor does not leave spaces behind, because if he has to fill these back spaces the neat cement would prove rather too expensive. These grout holes are sometimes left as weep holes as tests for water, but usually are plugged.

The waterproofing being so applied to the under side of the lagging, and the lagging serving as the top of the mold or form for the concrete, the waterproofing thus comes directly against the outside of the concrete, and as a fact the effect is successful.

The third place where waterproofing is applied is the floor of the subway. A thin subfloor is first laid, the waterproofing is put on that, and then the main floor is laid, so that in the floor and in the walls the waterproofing forms a diaphragm in the body of the concrete, but near its outer side, while on the roof the waterproofing forms a skin on the outer side of the concrete, but underneath the lagging, which in turn is saturated by and covered with a layer of rich grouting.

The temperature of the composition is about as warm as is comfortable for your hand, and it has been found that at this temperature the material flows readily and adheres in a thick skin to a vertical wall.

Loads and Upward Pressure

All subways in Boston are built to sustain eccentric loading, and especially to withstand upward pressure on the floor. There were places where the quicksand and water encountered made it very difficult to hold down the floor. In fact, there were places in New York where the structure actually floated. In some instances it was necessary to use bracing to hold down the floor of the open cut, quite as much as bracing to hold up the outer walls. In cases of this kind it was necessary to use a great deal of reinforcing steel in the concrete.

In one place a reinforced floor was built over a bed of quicksand. The subway in this place was like a ship floating in the water. The danger in the subway was that the floor would push up or the center line of piers push down into the soft material underneath. This is probably the heaviest reinforcing of any place that I saw.

Steel Forms

The contractor found it convenient to use steel forms, and he told me that these steel forms saved him a great deal of money and left the work in extremely good condition, and he also said that he would probably hereafter use them throughout his entire job. Where the subway was built by the cut and cover method it was necessary to use a great deal of reinforcing in the outer walls and in the roof, because the adjoining buildings, sometimes on one side and sometimes on the other, and sometimes on the roof, produced eccentric stresses, especially in those places where adjoining property owners had the right of excavation to below the subway level, and particularly where the subway was built in "filled ground" on unstable foundations.

Handling the Concrete

The method of pouring concrete used wherever the subway is under the street is to bring a dump cart full of concrete down the street in the regular line of traffic, stop for a moment, dump its concrete, and pass on. The concrete is slid down pipes with very little interference with traffic. Concrete mixers were placed on side streets or on an open space away from the traffic or on a side lot or some place out of the way. Then concrete was mixed in the mixers and hauled to the job. Of course there were places where the concrete mixer could be right on the job, but not in the crowded streets.

Cut and Cover Construction

In some instances the cut and cover construction was made with a center core. This system was employed in crowded streets. Procedure is as follows: A longitudinal trench is run under cover of planking so as not to disturb the traffic in the street any more than necessary. This trench is run along the line of one outer wall of the subway and is made just wide enough for the building of this wall. From the contractor's standpoint it is similar in all respects to a sewer trench, excepting that it is not in the middle of the street, but close against one side. When it has been finished a similar trench is run down the other side of the street, and the other wall of the subway built therein. While this second wall is being built the surface of the street has been undermined and is held up on timbers supported on what is now really the center core. Then the flat arch or slab is built, and the excavation of the core is undertaken throughout the line of the subway itself, and thus the handling of that great amount of material in the crwded streets is obviated. This method could not be conveniently employed in New York, because in New York subways are generally in hard rock. In New York it was necessary to take out the whole section of the subway at one time.

Twin Arch Sections

The principal part of the Boylston Street subway is built in what is called the twin arch section. In a typical section twin arches rest on the outer walls and on a center row of steel columns. This center row of columns will afterwards be concreted, sometimes as individual columns and sometimes as a straight wall. The object of the design is to keep down the total thickness of the walls to the least allowable amount, in order to obtain the greatest width possible for the subway. Concrete on the center columns is not figured for strength, but only

for protection against weather and injury. This tunnel for the greater part of its length is below water level.

In a typical example of a completed twin arch section the finished covering of the steel columns leaves them less than 12 inches thick. The walls are extremely smooth, and the resulting appearance of the tunnel is extremely satisfactory. The twin arch illustrates a most important point in subway design. In order to handle a double-track railway as built in Boston, or a four and six-track railway as frequently built in New York, it is necessry that there shall be frequent cross-overs from one track to another. In New York I found cases of six tracks connected by cross-overs at one section. This means that at these points of cross-overs there can be no support, and the span must be from outside to outside. In the instance here stated all the other measurements of the design, including thickness of exterior walls and floor, are the same as in the standard twin bore, excepting only an increase of the steel at the roof and floor. New York has a very considerable underground yard for storage, where cross-overs connect five parallel tracks in single span under a flat roof. The engineers tell me that since they have had experience in this class of work they do not hesitate to build these wide spans, and that they figure the roof largely as a slab supported on two sides, with haunches reducing the span. This is an important point for us to consider, in view of the discussion of whether we should build a single bore or double bore tunnel under First St. and Second St. There are many examples in New York and a few examples in Boston of wide spans carrying much greater overhead loads than we have here in Los Angeles.

Air Lock Method

The subway under the harbor, leading from Boston to East Boston, was, of course, built with a shield, because it was through mud nearly all the way, and, of course, was necessarily built by the air-lock method. The air-lock was a two-story type, which is now almost universal, and the upper floor was used for concrete and emergencies. The East Boston Tunnel is so successful that the new tunnel under the harbor, leading to South Boston, is to be almost a duplicate of the East Boston Tunnel, excepting that it is to be a twin-arch tunnel built in a somewhat novel way, but with the same general patterns of design, thickness of walls and of strength. The lower floor of the air-lock, corresponding to the lower floor of the shield, represented the regular working chamber.

Steel Beams and Brick Walls

The old subway, which was the first one built to carry electric cars, was built of steel beams with brick curtain walls. According to the practice of that time, the steel beams were built fully exposed. According to modern practice, the same steel beams are frequently used, but are always hidden under a smooth surface of concrete, which gives a much better and more satisfactory type of work. The headway of the old subway is about twice the height of ordinary persons. As a fact, it varies from 7 feet 9 inches to 14 feet. At the old Park Street station it is about 10 feet, which is considered ample headroom for heavy traffic.

Conflicting Property Rights

There were many conflicts between the right-of-way and the abutting properties which stood upon footings which extended into the street at shallow depths. The adjustment of these disputes at stations often resulted in great gain to both properties. At the Summer Street station one abutting property is Fillene's dry goods store, about corresponding to Bullock's or Hamburger's, and the show window is built as one wall of the station, although it is the third floor below the street. Naturally, it makes a very attractive show window, and is furnished with a private entrance leading through the stove to the elevators.

How This Applies in Los Angeles

One of the principal problems before us today in Los Angeles is the relief of the congestion of the retail shopping district. An analysis of the congestion shows that it is composed of traffic passing in and out of local buildings in the district, and also of a very heavy traffic which is merely in transit through that district, but is forced to pass through the district because there is no other way to go. Relief of this congestion is twofold. Let us consider the suburban traffic coming into the city. This traffic should be delivered to the center of the district as rapidly as possible, and should not be burdened by local stoppage at every street corner. From the point of view of handling a large number of people with the smallest number of street cars, it is foolish to stop a heavy three-car train for the purpose of letting on or off two or three passengers, and frequently no passengers, and it is extremely foolish to route these heavy trains through streets already crowded by long distance and local street cars and by automobiles and other vehicles, with stoppages at every crossing, under a system that provides the greatest possible interference between street cars and other street traffic.

It is proposed to build a tunnel under First St. and another tunnel under Second St., and we are now repairing the Third Street Tunnel. The object of this development is to provide improved and adequate means of communication between the congested business district of Los Angeles and the northern and western parts of the city, and to route out of the city, especially in the evening hours, the heavy homeward-bound traffic and get it out of the city by the shortest and quickest route, so that in so far as possible no traffic will pass through the business district excepting such as necessarily stops in that district for the transaction of business. In other words, to operate through traffic and get it out of the business district as quickly as possible. The people who will use these tunnels are the people who live in the northern and western parts of the city and beyond. By far the greater number of these people, fully 80 per cent, come and go between their homes and the business dis-

trict by means of street cars. If these people are called upon to pay for these improvements they should be built so as to be adapted to street car service; otherwise it cannot be said that these tunnels are a bona fide improvement justifiably charged against and paid for by people who cannot use them. If the tunnels can be made satisfactory for street car traffic without unduly increasing the cost, such a design is self-evidently superior to the proposed plan of building the tunnels so small that street cars can never operate through them, and tunnels adapted to the high speed traffic of street cars are the only equitable return which the city can make for the money it proposes to collect from the relatively small property owners in the assessment district.

One of the original designs heretofore proposed, and now in great danger of being accepted, advises twin bores at Second St., both of such low overhead room and narrow width that street cars can never operate through them with safety in any event, and cannot operate through them at all with the consent of the State Railway Commission, because both the safety of operation and the requirements of the State Railway Commission are that the tunnels must be 26½ feet wide in the clear, whereas the design now favored provides for twin bores only 24 feet wide. The late Councilman McKenzie saw this point very clearly, and at his suggestion an advisory commission was appointed to examine into the feasibility of building wider tunnels. This commission desired to retain as many elements of the original design as possible, and, therefore, did not raise the height of the tunnel as it otherwise would have done and as there is plenty of room to do, but brought back a report advising parallel tunnels 27 feet wide in the clear. It is proposed by this commission that these tunnels shall be built of concrete, and not of brick, as advised by the city engineer, and that the tunnels shall be built with an inverted concrete arch under the floors, in order to distribute upon the floor the load which rests on the arch and to distribute this load as uniformly as possible, and provide a safer and better wearing pavement. The principal difference between the 27-foot tunnels advised by the commission and the 24-foot tunnels heretofore proposed is that the thickness of the side walls has been reduced to 27 inches, carrying only such reinforcement as is necessary to take care of the load. A great gain has also been obtained in width by advising that the tunnels be built the full width of the right-of-way, which necessarily means that the tunnels will have one or more slight angles, but angles so slight as to have no effect upon capacity and to effect an increase of width, which in fact is an increase of one line of traffic, because, of course, you understand that the capacity of a tunnel is measured by the number of streams of travel which can pass through it, so that it is extremely practical for an addition of two or three feet in width to make an addition of one or more stream of traffic, and thereby double or even treble the capacity of the tunnel. The capacity of a tunnel may be described as the number of streams of traffic multiplied by their velocity, it being evident that two streams of traffic in a tunnel, one stream going in each direction, is limited in velocity to the speed of a walking horse somewhere in the line of travel, whereas if one more line of traffic can be had during the rush hours of the evening, and that line kept free of walking horses, it will immediately jump in velocity from three miles to twenty miles per hour, all with equal safety, as the various streams of traffic are separated into individual lines by longitudinal curbs.

The same commission brought back a preliminary report on the problem of the First Street Tunnel. The commission proposes one tunnel 27 feet wide in the clear for street car purposes; the other tunnel is proposed of the greatest available width, namely, 35 feet 6 inches. Here, again, reinforced concrete will be used without brick. It is advised by the commission that the pavement of all the tunnels be subdivided by curbs, making lines for vehicles, in order to enable the vehicles to make the fastest speed through the tunnels, it having been found that our present ordinance limiting speed to eight miles per hour is necessary in narrow tunnels without center curbs more on account of careless driving than on account of the actual width, so that vehicles in lanes properly separated by curbs can operate at much higher speed.

In the matter of asking the railroads to pay a cash sum equal to one-half the cost of the tunnel, I think I have made it clear to you what is the procedure elsewhere, namely, the leasing of the tunnels to the railroads either at a rental based on cost or based on the number of cars passing through. I can see no harm in asking the railroads to pay half the cost, and I think it would be very nice for the city and very nice for the people in the assessment district if the railroads would pay one-half of the cost, but I cannot understand how the financial scheme of the railroads will permit of any such expenditure of money for the temporary use of a tunnel, and if the railroads undertook to make such a payment I should feel that the State Railway Commission was extremely lax in its duties, a laxity which has not been shown, as it has already forbidden such payment. And if the railroads urged such a system of payments I should feel that railroad securities were no longer a safe investment.

Revised Roster of Members of the Association, November 1, 1914.

NOTE: All addresses are Los Angeles, Cal., unless otherwise specified.

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Ross, Ernest S., City Engineer's Office.

Sanborn, Kingsbury, 527 Marsh-Strong Bldg.
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Scattergood, Ezra F., 600 Knickerbocker Bldg.
Schank, Francis R., 526 Federal Bldg.
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Shultz, Clarence J., City Engineer's Office.
Simkins, Wm., 664 Pacific Electric Bldg.
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Sklar, Samuel B., 1306 S. Troy St., Chicago, Ill.
Slater, Elmer O., 245 S. Los Angeles St.
Small, Walter E., 1024 S. San Pedro St.
Smith, Herbert L., 2044 Fletcher Ave., South Pasadena, Cal.

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Smith, Thos. S., 126 S. Los Angeles St.
Smith, Walter Dorr, 5314 Marmion Way.
Smith, Warren T., City Engineer's Office.
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Spears, Chas. A., 1041 Monadnock Bldg., San Francisco, Cal.
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Strong, Archibald M., 530 Union Oil Bldg.
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Talcott, J. S., Jr., City Engineer's Office.
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Taylor, Horace N., 922 Blaine St.
Taylor, Waller, 938 Lake St.
Trask, Frank E., 616 Union Oil Bldg.

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Veuve, Erle L., 103 N. Ardmore Ave.

Wackerbarth, August, 202 N. Main St.
Waddingham, Albert B., 308 Tajo Bldg.
Waite, Marion P., 519 W. P. Story Bldg.
Walls, John A., 1136 Van Nuys Bldg.
Ward, Frank A., 1250 Leighton Ave.
Warner, Edwin H., 329 San Fernando Bldg.
Warner, Loring K., 421 Union League Bldg.
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Woodson, Jas. B., Rowell Bldg., Fresno, Cal.
Wright, Edward T., 466 Pacific Electric Bldg.
Wright, Geo. A., 466 Pacific Electric Bldg.
Wright, Jesse C., 471 Pacific Electric Bldg.
Wyman, Geo. H., 320 Henne Bldg.

HONORARY MEMBERS

Fries, Major Amos A., Yellowstone Park, Wyo.

ASSOCIATE MEMBERS

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Forman, Chas., 1210 Marsh-Strong Bldg.
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Iles, Harry, 122 N. Broadway.
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